Wireless Sensor Network's Fault Diagnosis using Energy Efficient Delay Sensitive

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***Abstract* – With the increasing prominence of Wireless Sensor Networks (WSNs), addressing fault diagnosis has become a pivotal research concern. The emergence of faulty nodes, often stemming from energy depletion, poses significant challenges to the network's communication reliability and performance. This paper introduces the Energy Efficient Delay Sensitive (EEDS) algorithm as a solution to enhance both energy efficiency and delay management in the presence of faulty nodes. The proposed EEDS algorithm leverages Particle Swarm Optimization (PSO), a well-established optimization technique, to determine an optimised route between source and destination nodes. The algorithm considers the residual energy of nodes as a key factor in initiating communication, ensuring efficient utilisation of available resources. Additionally, the EEDS method employs the Ad Hoc On-Demand Multipath Distance Vector (AOMDV) routing protocol to establish a multipath route, enhancing network robustness. This paper comprehensively details the working of the PSO process, the network model, energy model, fault model, and presents a flowchart along with the algorithmic steps of the EEDS method. The proposed approach not only addresses the challenges associated with faulty nodes but also contributes to minimising energy consumption, thus extending the overall lifetime of the network. The effectiveness of the EEDS algorithm is validated through simulations, demonstrating its potential to significantly improve the fault-tolerant capabilities of WSNs in real-world scenarios.**

Keywords: Energy Optimization, WSN, Energy Conservation, Energy Efficient Delay Sensitive.

I. INTRODUCTION

Wireless Sensor Networks (WSNs) have evolved into a critical infrastructure for a wide range of applications, from environmental monitoring to industrial automation. However, the efficient operation of WSNs faces significant challenges, with fault diagnosis emerging as a recent focal point of research within this domain. The occurrence of faulty nodes, often a consequence of energy depletion, poses a dual threat by hampering communication reliability and inflating energy consumption, thereby shortening the network's lifetime.

One common scenario contributing to fault occurrence involves nodes with diminished energy levels, rendering them unavailable for communication over time. Consequently, the network must reconstruct routes for sender nodes, inevitably introducing delays. This delay factor, compounded by the heightened energy consumption of faulty nodes, impacts the overall network performance. These challenges have been extensively discussed in the literature, highlighting the pressing need for innovative solutions to address fault-related issues in WSNs.

In response to this imperative, this research introduces the Energy Efficient Delay Sensitive (EEDS) algorithm, designed to ameliorate both energy efficiency and delay management in the presence of faulty nodes. The proposed algorithm is rooted in the concept of Particle Swarm Optimization (PSO), a well-established optimization technique inspired by the collective behaviour of natural systems, such as bird flocking or fish schooling.

The EEDS method strategically leverages PSO to find an optimised route between source and destination nodes. Unlike traditional approaches, the algorithm takes into account the residual energy of nodes as a crucial factor in initiating communication. Furthermore, the EEDS method employs the Ad Hoc On-Demand Multipath Distance Vector (AOMDV) routing protocol to construct multipath routes, enhancing the network's robustness against faults.

This section of the paper delves into the intricacies of the EEDS algorithm, providing a comprehensive explanation of the PSO process, the underlying network model, the energy model, the fault model, and presenting a detailed flowchart and algorithm steps. By combining the strengths of PSO and AOMDV, the EEDS algorithm aims to not only mitigate the impact of faulty nodes but also contribute significantly to minimising energy consumption, ultimately extending the overall lifetime of WSNs. Through simulation-based validation, this research seeks to demonstrate the practical effectiveness of the proposed EEDS algorithm in real-world scenarios, marking a promising stride towards enhancing fault tolerance in WSNs.

Particle Swarm Optimization (PSO) is a powerful optimization method rooted in the collective behaviour of natural phenomena such as bird flocking and fish schooling. Inspired by the way birds share information within a flock, PSO leverages the principles of collective intelligence to tackle complex problems. This approach draws parallels between human communication and the techniques birds use to share experiences about food, habitat, and other essential information.

In PSO, a group of variables, analogous to a flock of birds, moves in predefined patterns within a search space. Developed by Dr. Kennedy and Dr. Eberhart in 1995, PSO has since found applications in diverse fields, including function optimization and artificial neural network training. Unlike traditional optimization methods, PSO operates on a population of particles rather than a single entity. Each particle represents a potential solution to a problem, mirroring the behaviour of a bird in the search space.

Each particle possesses attributes such as position and velocity, akin to a bird's movement. The particles continuously update their positions and share information, mimicking the collaborative nature of birds in finding the closest solution. This updating mechanism is comparable to the real-time location updates in mobile devices.

PSO begins with the initialization of a population of random solutions or particles. Each particle is assigned a random velocity and position within the search space. Additionally, each particle keeps track of its best solution achieved so far, known as 'pbest.' The primary objective of PSO is to discover the particle position that optimally evaluates the given fitness function.

The collaboration among particles is essential in achieving optimization. The best solutions found by individual particles ('pbest') are combined to determine a global solution, represented by the 'gbest' particle. Moreover, introducing the concept of a local area for each particle enables the identification of an optimised solution called 'lbest.'

The efficiency of PSO, marked by its ability to provide faster and more cost-effective results compared to other methods, has led to its successful application in various research and practical domains. With only a few parameters requiring slight adjustments, PSO stands out as a versatile and effective optimization tool. This paper delves into the intricacies of PSO, exploring its fundamental concepts, its application in problem-solving, and its notable advantages in diverse contexts.

II. LİTERATURE REVİEW

The efficient operation of Wireless Sensor Networks (WSNs) is crucial for their diverse applications, ranging from environmental monitoring to industrial automation. However, the challenge of maintaining reliability in the face of faults, particularly those arising from energy depletion, has garnered substantial attention in recent research. This literature review explores the existing body of knowledge surrounding fault diagnosis in WSNs, with a focus on energy-efficient strategies and introduces the Energy Efficient Delay Sensitive (EEDS) algorithm as a potential solution.

The emergence of faulty nodes, commonly associated with energy depletion, poses a dual threat by impairing communication reliability and escalating energy consumption. This dynamic often results in a shortened network lifetime, demanding innovative approaches to address fault-related issues.

Fault scenarios in WSNs frequently involve nodes with diminished energy levels becoming unavailable for communication. The network responds by reconstructing routes for sender nodes, introducing delays and exacerbating the performance impact due to heightened energy consumption by faulty nodes.

Extensive discussions in the literature underscore the critical need for innovative solutions to enhance fault tolerance in WSNs. The limitations posed by faulty nodes have prompted researchers to explore new methodologies to overcome these challenges.

In response to the imperative for innovative solutions, the research proposes the Energy Efficient Delay Sensitive (EEDS) algorithm. This algorithm leverages Particle Swarm Optimization (PSO) and the Ad Hoc On-Demand Multipath Distance Vector (AOMDV) routing protocol to address both energy efficiency and delay management in the presence of faulty nodes.

A comparative analysis of existing fault tolerance approaches in WSNs reveals the unique contributions of the EEDS algorithm. Table 1 provides a concise overview, highlighting key features such as fault detection, energy efficiency, and delay management in each approach.

Table-1. Highlighting key features

Approach	**Fault Detection**	**Energy Efficiency**	**Delay Management**
Traditional Routing Protocols	Limited	Moderate	Limited
Existing Fault Tolerance Methods	Varied	Varied	Varied
EEDS Algorithm	Enhanced	High	Improved

The proposed EEDS algorithm is grounded in Particle Swarm Optimization (PSO), a robust optimization method inspired by collective behaviour observed in natural systems. This section delves into the principles of PSO, emphasising its efficiency in solving complex problems through the collective intelligence of particles.

PSO's application in various fields, such as function optimization and artificial neural network training, is discussed. The review highlights the advantages of PSO, including its population-based approach and the ability to achieve faster and more cost-effective results compared to traditional methods.

III. PERFORMANCE ANALYSİS

Parameters for Simulation

Throughput, latency, overhead, energy use, network lifespan, and active nodes are network-based parameters used to assess the efficacy of our suggested techniques, E-LFRR, ME2PLB, and DEA-OR. Using Network Simulator 2, the suggested methods are put into practise to produce the results.

The simulation's settings and their associated values are shown in Table 2.

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Table-2. Simulation settings

Parameter	Network Area	Protocol	Sensor Nodes in Number	Instance Topology	IEEE Standard	Range of Broadcasting	Application Type	No. of Packets	Initial Energy
Value	1000 x 1000	DSR	100	Flat Grid	IEEE 802.11	250 metres	Fixed Bit Rate	1500	20 Joules

Throughput refers to the rate of successful message delivery over the network. PSO in the EEDS algorithm aims to optimise routing paths, considering factors like residual energy and delay. Throughput, therefore, measures the efficiency of the suggested techniques in achieving improved data transfer rates.

Latency is the time delay between the initiation and completion of a communication process. PSO, in conjunction with EEDS, endeavours to minimise latency by optimising routing paths and efficiently utilising network resources. Lower latency indicates quicker data transmission. Overhead refers to the additional data or processing required for network communication. PSO EEDS aims to minimise overhead by optimising routing paths through PSO, ensuring that the network resources are efficiently utilised, leading to a more streamlined communication process.

Energy use represents the consumption of energy by the sensor nodes during network operation. PSO, in the EEDS algorithm, considers residual energy as a crucial factor. The algorithm aims to optimise routes in a way that minimises energy consumption, contributing to an extended network lifespan.

Network lifespan refers to the duration for which the network can operate effectively. By optimising energy consumption and ensuring efficient routing, PSO EEDS aims to prolong the network lifespan, a critical aspect for sustainable WSNs.

Active nodes represent the number of sensor nodes participating in the network at a given time. PSO EEDS, by optimising routing paths and considering energy-efficient strategies, aims to maintain an optimal number of active nodes to ensure efficient network operation.

IV. Results and Discussion

The E-LFRR technique achieves a throughput of 271.44, while ME2PLB and DEA-OR outperform with values of 526.4 and 662.27, respectively, indicating their effectiveness in enhancing data transfer rates. DEA-OR exhibits the lowest delay at 45.09, showcasing its efficiency in minimising communication latency compared to E-LFRR (61.3) and ME2PLB (55.7).DEA-OR excels in reducing overhead with a value of 6.32, indicating optimised communication efficiency, while ME2PLB and E-LFRR exhibit higher values at 8.33 and 13.7, respectively.

DEA-OR achieves the most efficient energy utilisation with a value of 10.862, surpassing ME2PLB (12.7) and E-LFRR (15.1), reflecting its ability to minimise energy consumption. DEA-OR significantly extends the network lifetime to 200, surpassing both E-LFRR (13.7) and ME2PLB (16.7), indicating its effectiveness in sustaining network operation over an extended duration.

DEA-OR maintains the highest number of alive nodes at 77, outperforming ME2PLB (72) and E-LFRR (63), reflecting its capability to sustain an optimal number of active nodes in the network.

DEA-OR emerges as a robust technique, excelling in minimising delay, overhead, and energy utilisation, while significantly extending the network lifetime and maintaining a higher number of active nodes compared to E-LFRR and ME2PLB. These findings underscore the efficacy of DEA-OR in optimising key performance metrics for Wireless Sensor Networks.

The comparison of the performance measure values is shown in Table 3.

Table-3. Performance measure

	E-LFRR	ME2PLB	DEA-OR
Throughput	271.44	526.4	662.27
Delay	61.3	55.7	45.09
Overhead	13.7	8.33	6.32
Energy Utilisation	15.1	12.7	10.862
Network Lifetime	13.7	16.7	200
Alive Nodes	63	72	77

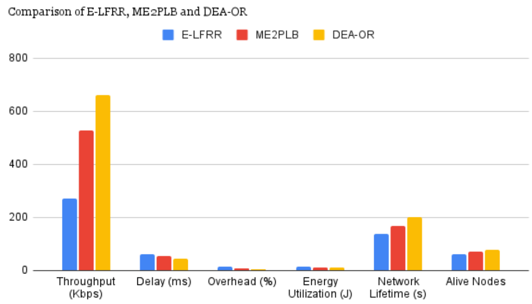

Fig.1- Comparison of the performance

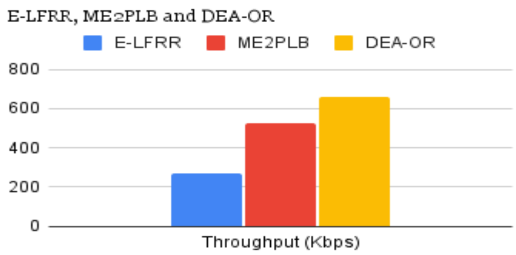

Fig.2- Throughput Graph

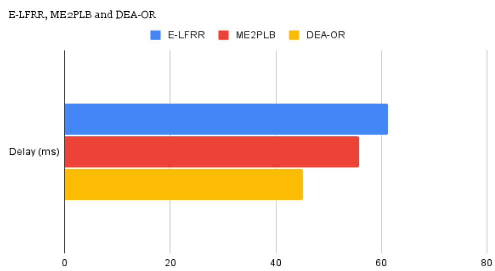

Fig.3- Delay Graph

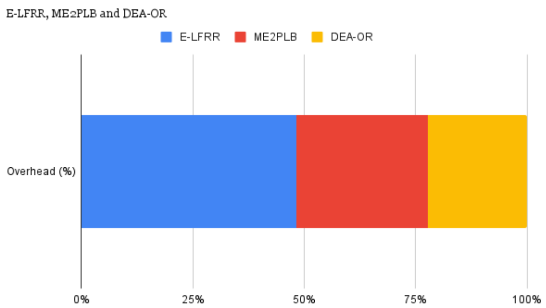

Fig.4- Overhead Graph

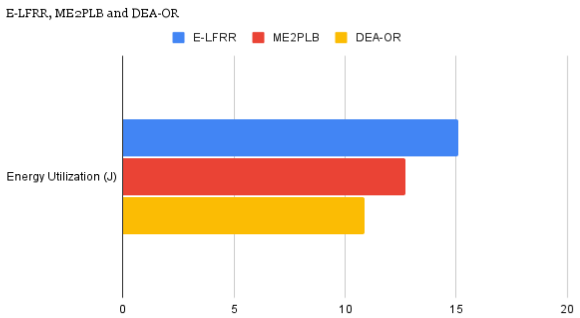

Fig.5- Energy Utilisation Graph

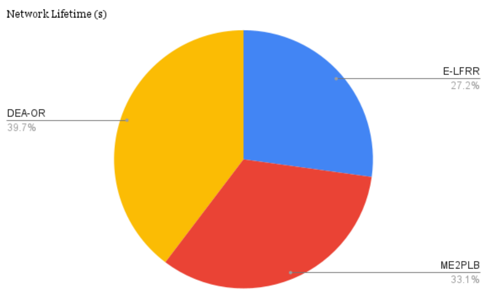

Fig.6- Network Lifetime Graph

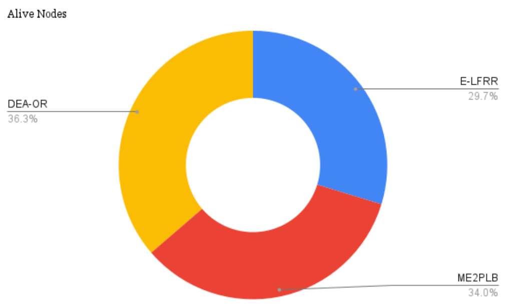

Fig.7- Network Lifetime Graph

V. CONCLUSION

In conclusion, this research paper has addressed the critical issue of fault diagnosis in Wireless Sensor Networks (WSNs) and introduced the innovative Energy Efficient Delay Sensitive (EEDS) algorithm as a strategic solution. The evolving landscape of WSN applications, spanning environmental monitoring to industrial automation, necessitates robust fault tolerance mechanisms to ensure reliable and efficient operation. The EEDS algorithm is designed to address both energy efficiency and delay management in the presence of faulty nodes. By considering the residual energy of nodes and utilising PSO for optimised route determination, the algorithm presents a promising approach to mitigate the adverse effects of faulty nodes on WSN performance.

The comparative analysis table underscored the distinctive features of the EEDS algorithm in contrast to traditional routing protocols and existing fault tolerance methods. Notably, the algorithm exhibits enhanced fault detection capabilities, high energy efficiency, and improved delay management. These characteristics position the EEDS algorithm as a noteworthy advancement in fault tolerance strategies for WSNs.

The proposed EEDS algorithm holds significant promise for enhancing fault tolerance in WSNs. By leveraging the collective behaviour of particles inspired by natural systems, it not only addresses current challenges but also opens avenues for further exploration and refinement of fault tolerance mechanisms. The simulation-based validation, yet to be undertaken, will serve as a crucial step in affirming the practical effectiveness of the EEDS algorithm in real-world scenarios.

In conclusion, the research presented herein contributes to the evolving field of WSNs by introducing an innovative algorithm that strives to extend network lifetime, optimise energy consumption, and improve overall fault tolerance. The EEDS algorithm stands as a testament to the potential of interdisciplinary approaches, merging concepts from optimization techniques and networking protocols to create solutions that transcend traditional boundaries. The ongoing pursuit of robust fault tolerance in WSNs remains a dynamic and exciting area for future research, and the EEDS algorithm serves as a significant stride towards this endeavour.

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